

HIGH-INTENSITY π BEAMS

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August 9, 1968

This is the result of a short investigation into the requirements and uses of a very high-intensity π beam. No attempt was made to make detailed calculations. The purpose was to determine roughly what intensity was practically attainable and what components would be needed to produce such a beam. Given such a beam, are there any insuperable problems in exploiting it using existing techniques?

In designing the beam, I arbitrarily picked an upper momentum limit of 100 GeV/c. This was based partially on the fact that present guesses on production using 200 GeV/c protons show that the π production cross sections drop rapidly above this energy. The various production curves (CKP, Trilling, Hagedorn) differ by a factor of 5 at 100 GeV. I have used the lowest of these (Hagedorn) in making my estimates. To attain a high flux of π 's it is necessary to use 0^0 production. A reasonable acceptance criterion for the beam solid angle is $\theta = 0.5/p$. Beyond this "Cocconi Disc" the additional intensity gained is not worth the price paid in quadrupole size. Thus, at 100 GeV/c we have $\theta = 0.005$ rad. At lower energies the intensities attainable will be higher than at 100 GeV/c for the same geometry, possibly a factor of 5 higher at 50 GeV/c.

In addition to this acceptance cone we have chosen a $\pm 5\%$ momentum bite. We have also assumed 10^{13} protons/pulse. The beam will then yield approximately $3 \times 10^9 \pi^-$ /pulse. The quadrupole system will, of course, not accept a circular disc of solid angle. There will, therefore, be some reduction in solid angle. There are other things which affect intensity, such as the "effective" momentum bite which must enter a detailed beam calculation. The uncertainty in the production curves is so much larger than these corrections that it did not seem worthwhile to worry about these details for a rough calculation.

I have arbitrarily chosen a 20 cm quadrupole aperture. This will be placed at an effective distance of $0.10/0.005 = 20$ meters to accept the desired solid angle. Standard nonsuperconducting quadrupoles approximately 3 meters long will permit a focus at around 70 meters from the production target (using thin lens approximation). The bending magnet needed will have a strength of about 80 kG-m with a 15 cm gap height. This will supply a dispersion of about 5% per inch. Thus, all magnets, while somewhat expensive, are well within the limits of present technology.

Such a beam has too large a momentum bite and too wide an angular divergence to provide any useful kinematic constraint on a reaction. The beam is too intense for use of any conventional detectors which react to individual particles. Thus, one will not know the momentum, or angle of the incoming particle in a reaction within broad limits and one cannot use a Cerenkov counter to determine its identity. This limits the

usefulness of the beam to those reactions in which sufficient constraints may be found from measurements of the outgoing particles.

The simplest such reaction to study, and probably the most interesting, is $\pi^- + p$ elastic scattering. Extrapolating from lower energy data, it is unlikely that such an intense beam will be needed for $-t < 2.5$ $(\text{GeV}/c)^2$. Thus, the experiment to be considered is elastic scattering for $2.5 < -t < 4$ $(\text{GeV}/c)^2$. To have sufficient constraints one must measure the opening angle of the two outgoing particles and their momentum. The kinematics is such that an experiment which subtends about 20% of the azimuthal angle and the entire t region mentioned above is quite feasible. Assume a 1 foot H_2 target. We then have one interaction per pulse for a $d\sigma/dt$ of about $10^{-33} \text{ cm}^2/(\text{GeV}/c)^2$. A reasonable event rate would still be attained at $10^{-35} \text{ cm}^2/(\text{GeV}/c)^2$.

For such a small cross-section experiment obviously has serious background problems. Only an extremely careful consideration of sources of background will show what accuracy is needed for various parameters to eliminate this background. A guess based on experience at lower energies indicates that 0.1% in momentum for each particle and a corresponding accuracy in opening angle (which will be needed anyway for the momentum measurement) will not be sufficient.

A screen of π^0 and charged particle anticounters in all directions other than the t region above will be needed. These are right on the edge of saturating at beams of 10^9 . There will be all kinds of other accidental problems, especially so since the forward particle will be

very close to the intense π beam. It may have to be bent away with a septum before detectors can be used. Since at these large t 's it is quite conceivable that $\bar{p} - p$ or $K^- - p$ cross sections might be much larger than $\pi^- - p$, one must use a Cerenkov counter on the scattered particle to assure that it is a π , since the elastic scattering of the other particles cannot be separated from $\pi - p$ kinematically.

The best way to approach the background problem is slowly. A target station should be flexible enough to handle a beam with the characteristics described above but before committing oneself to a specific design the experiment should be run to as large a t as possible with conventional (10^7) π beams. It may be that the background problem is so severe that the only approach with any hope of success will be to bring out a beam which is rather accurately parallel and 8 inches in diameter, then use a hodoscope of many counters, all operating at levels around 10^7 per pulse to supply momentum, and, more important, angular constraints on the incoming particle. Such an experiment would be very complex but may be needed to realize the use of the full π intensity inherently available from the accelerator.